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Research Paper no. 16/00

Environmental Kuznets Curves and some Danish Experiences

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Abstract

This paper discusses the interpretation of environmental Kuznets curves as manifestations of endogenous delinking of environmental pressure. The paper examines the results in the empirical literature and finds it does not support the hypothesis of endogenous delinking. It is concluded that the evidence does not support the hypothesis as a general economic law. This can, however, be a result of inadequate specification of the statistical models used for testing the hypothesis. The effects could be present without dominating the development of environmental pressure, which is also driven by other forces.

Even if they are not sufficiently powerful to manifest themselves in the overall relationship, their existence and strength are important to know in long term environmental policy. To get some idea of the magnitudes of such forces, some Danish experiences with energy related pollutants, energy consumption, and some political economy aspects of environmental policy are analysed.

Energy consumption is the main factor determining fossil fuel related environmental pressure. The statistical evidence actually displays some delinking of energy consumption from economic growth. The question is whether this is more or less endogenously a result of the high income level in Denmark. The evidence found suggests that it can not be rejected that delinking mechanisms related to a high level of income has played a role in Denmark, but if they have, their impact has been small or negligible.

Keywords:

Economic growth, environmental quality, Envionmental Kuznets Curves (EKC), Denmark, energy consumption, fossil fuel related emissions

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some Danish Experiences

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TABLE OF CONTENTS

Environmental Kuznets Curves

Recent research has found statistical patterns relating environmental quality to economic growth in a positive fashion for high-income economies. This is an observation that challenges the standard assumption of many economic analyses that environmental pressure increases as the level of economic activity increases. The study of those patterns has gained increasing attention in the 1990's under the label *Environmental Kuznets Curves* or *EKCs*.

This name is due to the resemblance to Kuznets' (1955, 1963) observations. He found a common pattern of the relation between income inequality to income level over the development phases of an economy. Kuznets found that inequality rises with income level as an economy develops until a certain point. Beyond this point inequality seems to decline again as income levels rise further and the economy becomes a high-income economy. He explained the findings by a more unequal income distribution in urban sectors than in the agricultural sector. Early growth of the urban sectors, thus reduce the relative weight of the more equal agricultural economy and expands the weight of the less equal urban sectors. As industrialisation and urbanisation proceeds, however, income disparities *within* the non-agricultural sectors tend to shrink. Eventually, this forces may outweigh the inequality arising from the sectoral structure changes. At least, this was the general finding for the developed economies during the first half of the 20th century.

Graphically, the relationship has the shape of an inverse "U". Similar secular patterns have been observed in studies of the relations between environmental pressure and growth and this has led to the hypothesis of the environmental Kuznets curve. Grossman (1995) provides an excellent overview. Other important papers include Hettige et al. (1992), Shafik and Bandyopadhyay (1992), Selden and Song (1994), Cropper and Griffith (1994), Holtz-Eakins and Selden (1995), World Bank (1992, 1996), and Stern (1996).

In a comprehensive study Grossman and Krueger (1995) analysed the effect of economic growth on a number of local pollution indicators relating to urban air pollution and contamination of river basins. Their conclusions were remarkable:

"Contrary to the alarmist cries of some environmental groups, we find no evidence that economic growth does unavoidable harm to the natural habitat. Instead we find that while increases in GDP may be associated with worsening environmental conditions in very poor countries, air and water quality appear to benefit from economic growth once some critical level of income has been reached. The turning points in these inverted U-shaped relationships vary for the different pollutants, but in almost every case they occur at an income of less than $8,000 1985-dollars. For a country with an income of $10,000, the hypothesis that further growth will be associated with deterioration of environmental conditions can be rejected at the 5 percent level of significance" (p. 370f).

This interpretation of the EKC hypothesis suggests that the inverted U-shape relationship between the level of economic activity and its environmental pressure be close to an *economic law*. Grossman and Krueger do stress that the process of delinking environmental pressure from economic growth has not been an automatic one (p. 371). They also stress that there is nothing inevitable about the relationships that have been observed in the past (p. 372).

However, a prediction based on past experience that at least 95% of the rich countries will experience economic growth and environmental improvement must rest on some causality between the level of economic activity and some relief of the environmental pressure. It requires the existence of some mechanisms that *endogenously delinks environmental pressure* from economic activity.

Naturally, this is not a claim that can be left undisputed and the 1990s have seen a large number of contributions to that debate. The following chapter reviews this debate by discussing the possible mechanisms that could bring about such an endogenous delinking and the results from empirical EKC studies. The findings are summed up at the end of the chapter. The rest of the paper examines the Danish data for evidence of endogenous delinking in Danish data from the recent decades. Since Denmark is a rich country, you would expect to find some of these mechanisms working in the Danish economy.

Possible Mechanisms behind Endogenous Delinking

Many EKC-studies are not very explicit about the theoretical background for expecting to find EKC patterns. A number of possible explanations are, however, provided by Hettige et al. (1992), Shafik and Bandyopadhyay (1992) and Selden and Song (1994). They don't form a coherent theory but they can be grouped according to type of relationship: structural and political economy explanations.

The *structural* explanations include the shifts in industrial and final demand structure as the economy runs through different phases of industrial development and the impact of high rates of investment. Hettige et al. (1992) describe the broad phases in industrial development as dominated by, first, agroprocessing and light assembly, then, heavy industry, and finally, high technology industry. Since heavy industry is more polluting than the other industries, this could be an explanation for observed EKCs. This explanation is in line with Kutznets' original finding of increasing inequality in the initial stages of industrialisation and urbanisation and declining inequality as the non-agricultural sectors in general and the service sector in particular develops. A related idea is that the *technological* development in developing countries cause the materials- and energy efficiency in manufacturing to improve dramatically. To explain the EKC pattern this would have to involve a regular jump from a lower to a higher standard at a certain per capita income level. Hettige et al. (1992) did, however, find that the toxic intensity of manufacturing output rose monotonically with the income level of the country.

A second structural explanation relates to the development patterns of *urban structures* (Selden and Song 1994). The industrialised countries have typically experienced a pattern of localisation of air polluting industrial activity in urban centres in early stages of development. As economic development has continued, it has turned out to be more expedient to relocate industrial activity to locations outside urban centres where land prices are lower and accessibility of heavy transport is better. As a result, urban air quality can improve in spite of increasing fossil fuel use because of relocation of its combustion.

The third structural explanation concerns the changes in the *structure of aggregate demand* that are related to the speed at which countries proceed to higher levels of income. One direction of change is the shift of aggregate demand from manufactured output to less pollution intensive services. Hettige et al. (1992) found that this shift was responsible for the EKC patterns of toxic intensities, they observed. Shafik and Bandyopadhyay (1992) found that the energy related pollutants sulphur dioxide and carbon dioxide are correlated with physical *investments* in production and transport, while access to safe water and sanitation and SPM emissions are not. Thus, rapidly industrialising economies would for this reason alone experience rates of increase in emissions of sulphur dioxide and carbon dioxide that are higher than the rate of economic growth because *investment rates are very high*. As noted below, rapid industrialisation may also simply make it more difficult for the authorities to keep pace with the need for appropriate environmental regulation.

The structural explanations may explain a levelling off of the increase or even of the level of environmental pressure as incomes grow beyond the turning point. To the extent they reflect relocation of industrial activity within a country or across country borders, they do however have a flip side mirroring the changes at other locations. Thus, environmental Kuznets curves may reflect displacement of particularly polluting production from richer to poorer countries or from urban to non-urban locations. Hettige et al. (1992) found that that toxic intensities grew most quickly in OECD countries in the 60s whereas the growth rates of toxic intensity were highest in the developing countries in the 70s and 80s. Thus, a fourth possible explanation could be the *structure of international trade*.

The second group of explanations has to do with the *political economy of environmental regulation*. That is, the interplay between economic conditions, political power, collective preferences, and the functioning of the political process.

One explanation is, that people care more for the environment when their basic needs have been satisfied (e.g., Beckerman 1995). Put in economic terms, the preferences for environmental quality are often assumed to be characterised by environmental quality being a luxury good, at least above a certain level of income. That is, when income increases, demand for a luxury good increases more than proportionally. When the demand for environmental quality is reflected in effective pollution control, it creates a downward force on environmental pressure that eventually, as income increases to high levels, becomes stronger than the upward pressure from the growth of economic activity.

This assumption fits nicely with another standard assumption in economic analysis of declining marginal utility of consumption. It has also found some support in cross-section analysis of willingness-to-pay for environmental improvements. The empirical evidence is, however, not conclusive on this matter (for a critical survey of the findings, see Kriström and Riera, 1996).

Even if these assumptions are realistic, they also require a range of assumptions of political economy to be able to explain EKCs. They require that the environmental preferences of the citizens actually be reflected in effective environmental regulation. There must be a political and administrative system that effectively transforms the individual preferences to collective preferences, set environmental goals and adopts regulation instruments in accordance with these, and implements this environmental policy effectively. It is often assumed that political leaders in the third world are more responsive to the urban population than to the rural population. The health effects of environmental pollution in urban areas could thus be assumed to get more attention and eventually result in inexpensive solutions such as relocation of polluting industries from urban centres. On the other hand, it would rather optimistic to assume these mechanisms to function promptly and effectively in all countries at any time and for all pollution problems.

On the other hand, you would expect that economic development is associated with a growing urban middle class, with a growing level of education, and with political influence. If the primary political base of the government is found in the urban areas, which seems to be usual in many developing countries, then one explanation can be as follows: In the initial development phases, the expanding non-agricultural sector may have disproportionately large political influence. This may give it freer hands to expand without paying attention to externalities imposed on the rest of the society. While the urban middle class grows, it may gain more political influence and also, as its income level grows, get stronger preferences for environmental qualities. The better education of the urban middle class compared to the agricultural population may also play a role in this process.

The stronger environmental preferences associated with the income growth in the non-agricultural sectors would then have increasing impact on government regulation which eventually could reverse the increasing environmental pressure from the expanding sectors.

In order for income elasticity of environmental control to serve as explanation of EKCs it is, however, necessary to take the income elasticities of other goods into consideration. If some goods with very low eco-efficiency in production or consumption are very income elastic as well, the net result could be a deteriorating environment. Personal transportation and housing requirements (heating and cooling) could be candidates for that category of goods.

Another explanation in this group is the simple fact that there are *time lags* involved in collective action. It takes time for the general public to identify a problem as a public problem. It takes time to form an appropriate regulatory response and to get sufficiently political support for its adoption. Finally, it takes time to implement it, to get the regulations to work in practice, and for the environment to recover. Naturally, the less effectively the political process functions in each of these links, the larger the lags from the emergence of environmental problems to their redressing. Environmental Kuznets curves could then be explained by the time that it takes to redress an environmental problem through environmental regulation. If this is the case one would expect smaller Kuznets curves (shorter lags) the more a country is characterised by political openness, democracy, and effective government.

Empirical EKC Studies

The World Bank (1992) provided evidence of this relationship interpreting it as a sign of *de-linking* of pollution from economic growth in OECD countries. Some of the studies show the bell shaped relation between concentration of sulphur dioxide and income level. The World Bank, however, also noted that CO_2 emissions, dissolved oxygen in rivers, and municipal wastes tended to rise monotonically with income level, while the opposite was true for sanitation access for urban populations and for urban air pollution of particulate matter.

One of the studies, the report was based on was Shafik and Bandyopadhyay (1992), who reported inverse U curve relations to GNP per capita for suspended particulate matter (SPM), and sulphur dioxide. For deforestation dissolved oxygen in rivers the results were not significant at a 5% level. For municipal waste and carbon dioxide emissions they found that these problems, indeed, increase with economic growth with no sign of a turning point. Lack of access to clean drinking water and sanitation, however, generally improved with rising income, irrespective of income level. Faecal coliform in rivers was worsening with rising income level in low-income economies, but improving in middle and high-income economies.

The statistics behind the Grossman and Krueger (1995) conclusion (see above) were not conclusive for all pollutants. In fact, inverse U shaped or monotonically decreasing relationships were only found in the cases of particulate and smoke pollution of the urban air and the cases of nutrients and faecal coliform in rivers. In the cases of sulphur dioxide in urban air, total coliform in rivers, and heavy metals in rivers, the results were an N-shaped relationship between income level and pollution. That is, pollution of urban air and rivers with these pollutants tend to first rise, then decline, and then rise again as the income level increases from the lowest to the highest level.

According to the authors, these results were due to the chosen form of the statistical model which, in combination with relatively few observations for high-income countries forced the relationship into a cubic form. By definition this has asymptotic properties. Therefore, the N shaped curves resulting out of some of the tests were not considered important.[1]

Eakin and Selden (1995) studied the global pollutant, CO2, and found that although the data suggested a diminishing marginal propensity to emit, it was far from enough to offset a monotonically increasing relation between national income and CO2 emissions. The turning point was estimated to be $35,428 per capita in one model and above $8 million in another.

Selden and Song (1994) examined the relation between four fossil fuel pollutants (SO2), Suspended Particulate Matter (SPM), NOx, and CO and the level of income. The data confirmed the inverse-U shape hypothesis but the curves peaked at a much higher level of income. On the global scale, they calculated that the turning point would appear at best at the end of the 21st century. An additional explanation for this is that the fastest growing economies in the world are on the rising section of the inverse-U curve.

The N-shaped relationship between environmental pressure and economic development was, however, confirmed by a study by Bruyn and Opschoor (1994). They examined the development of an aggregate index of materials consumption in the European countries and found such a relation in most of the countries studied.

Torras and Boyce (1998) also reported N-shaped relationships. Their primary concern was, however, the political economy relations between power distribution and environmental regulation. They found some evidence that could be interpreted as a dependency of environmental quality on power distribution independently of income level. Power distribution was in turn defined by income distribution, literacy, and an index for liberties and rights.

Hettige et al. (1997) analysed industrial wastewater pollution with, primarily, organic substance. They found that pollution of this kind tends to increase

[1] It is not clear why the same error should not appear when using a quadratic form for the statitical model.

with economic activity at low levels of income and then to level of and stabilise at an income levels of $US 7,000 per capita and beyond. That is, the curve doesn't bend downwards. The stabilisation is explained by a stricter environmental regulation as countries get richer. However, it does not necessarily imply that pollution is stabilised at the optimal or at any other desired level.

The Danish Ministry of Finance (1996) estimated statistical models explaining the variation in environmental indicators among 123 countries by variations in GDP per capita. The models used for the tests included linear, log- linear, log-log, and quadratic models.

The statistical results showed that the variation in some of the environmental indicators is better explained in log-linear than in quadratic models. This is the case for access to drinking water and sanitation as well as for the concentration in urban air of particles and SO2. Particle emissions and fertiliser inputs do, however, seem to be well explained by a quadratic model, suggesting an inverse U shape. The CO2 emissions are explained by a log-log relationship with elasticities ranging from 0.9 to 1.4 depending on the year.

Cropper and Griffith (1994) estimated the relationship between deforestation and real per capita income and found inverse U-curves for Africa and Latin America but failed to find any for Asia. They could, however, not conclude that the problem would be solved if incomes grew sufficiently. The turning point for both continents was at a far too high rate of deforestation and too high a level of income. The analysis only showed that the increase in the rate of deforestation seems to level off as income increases for the economies in the sample.

Similarly, Suri and Chapman (1998) found an EKC for energy consumption over an irrelevant large span of income (turning point app. $56,000 (1985, PPP), $224,000 with trade).

The only evidence of a real and relevant EKCs seems to be that of SO_2 and SPM. Stern et al. (1998) reviewed five studies of SO_s curves that all confirmed the existence of an SO_2-EKC, but with turning points ranging from U$ 2,900 to US$ 12,300 per capita. They carried out a study on a new comprehensive data set and found the hypothesis of a universal EKC poorly supported. Estimating such an EKC resulted in a turning point at US$ 78,700 per capita. The difference between these results and the previous was assessed to be due to the poor coverage of the previous datasets. They included relatively few observations for developing countries.

However, another important difference is that the Stern et al. (1998) study was concerned with SO_2 emissions rather than ambient air quality. This difference is important because it does not exclude the possibility that the environment is capable of absorbing increasing pressure. Aggregate emissions may be affected by structural changes, but the severity of emission growth depends on the concentration of the emissions.

Kaufman et al. (1998) drew attention to this point in a study combining emission data with emission concentration data. They found an inverse U-form of SO_2 concentrations over a concentration index but a *regular* U form of SO_2 concentrations over income levels. Thus, the EKCs found may be reflecting geographical concentrations of economic activity rather than income levels.

Bruyn and Opschoor (1994) and Bruyn et al. (1998) investigated the empirical evidence of the EKC and the de-linking hypothesis. The criticisms of these studies was that in the EKC studies, cross section data was used to study longitudinal processes, that the econometric models used lacked asymptotic properties, and that they did not distinguish between structural change and economic growth.

The studies made use of alternative regression models for testing the statistical relationship between energy consumption (and energy-related emissions) on the one hand and economic growth on the other hand. Each model was estimated for a number of OECD countries.

The conclusion was that the results did not support the de-linking hypothesis. Intensity of energy consumption was declining but rather as a function of time than as a function of income.

Summary of the Findings and Some Conclusions

The empirical evidence reviewed above suggests that the EKC pattern is not a *general* pattern of environmental pressure and economic growth. It has only been observed within relevant income intervals for urban pollution problems. Moreover, the inference of endogenous delinking is seriously challenged by the findings that EKCs may rooted in urbanisation patterns and geographical concentration patterns.

Grossman (1995) reviewed the until then published empirical studies and concluded that "the turning point of the relationship between pollution and national output had come soonest for those dimensions of environmental quality that have a direct and immediate connection to local health and well-being."(p. 44)

In the light of the preceding section, this conclusion can be sharpened. There is no evidence that economic growth in itself does anything than increases the environmental pressure on international and more invisible environmental problems.

The empirical findings suggest that pure EKCs can only describe SO2 and SPM urban air pollution. Progress in the control of river pollution by organic substances and access to sanitation also shows an optimistic picture, although not an inverse U-curve. The rest of the studies find either monotonically increasing curves, N-shape curves, curves that first increases and then levels of, or inverse U-curves over irrelevant income intervals. Even the SO_2 curves found are questioned by recent research.

The conclusion is that there is no *general* empirical evidence of the EKC hypothesis as an economic law. For urban air pollution of SO_2 and SPM the EKC hypothesis as an economic law cannot be rejected, but as Grossman (1995) stresses there is nothing automatic about it. Moreover, recent contributions have questioned the inference and generality of the findings.

A paper by Arrow et al. (1996) established a remarkable consensus on these issues among a group of economists and ecologists with high international reputation. This paper also concluded that, the observed EKCs show that urban air quality can improve alongside with economic growth but not that it necessarily does or that, when it does, it is sufficient and timely. As to policy conclusions, the paper stated that "economic liberalisation and other policies that promote gross national product growth are not substitutes for environmental policy" (p. 109).

Grossman and Krueger (1996) replied that they agree with that conclusion. "But we would go further and state that neither is suppression of economic growth or of economic policies conducive to it a suitable substitute for environmental policy" (p. 121).

If both of these policy conclusions are representative, we can cautiously derive a consensus among economists that economic growth *per se* is neither the cause of environmental deterioration nor of environmental protection. This brings us back to the hardly surprising conclusion that the state of the environment is the result of the environmental *policies* - including laissez-faire policy - that are pursued.

Then we should look upon the EKC as one of several alternative *options* for development strategies rather than an economic law. The EKC studies provide evidence that such a strategy has been feasible in the past for SO_2 and SPM urban air pollution. They also shows that a strategy of continuously improving access to drinking water and sanitation even in low income economies has been feasible.

Munashinghe (1995) points to the possibility of following a "tunnelling through" strategy rather than an EKC strategy by introducing environmentally justified reforms at early stages. One example of such a reform could be to eliminate energy subsidies.

The above list of mechanisms that could control the link between eco-efficiency and the level of economic activity is interesting even if they have not been confirmed as determining the general growth-environment pattern. Even if they are not sufficiently strong to outweigh the environmental impact of growing economic activity, they can have effects that should be taken into consideration when predicting the environmental pressure from the anticipated economic growth.

In the following sections, I shall investigate the working of these mechanisms in the economic development experienced by Denmark in the later decades. I confine the study to environmental pressure related to the use of fossil fuels.

Most of the EKC-literature deals with general macro relationships between growth and environment using panel data or cross-section data from a sample of economies. While most of the studies reviewed above make use of this approach, I concentrate on the *history of a single economy* to facilitate identification of structural and political economy factors behind the development.

Of course, there is no guarantee for the generality of the results. On the other hand, the entire scientific program of analysing a panel of different countries at different stages of development rests on the premise, that there are some common patterns that all countries more or less follows. If this is the case, then the Danish economy should have already passed through the known development stages and the experience of environmental problems associated with these stages should be of some general interest.

Fossil Fuel Related Emissions in Denmark

EKCs for Fossil Fuel Related Emissions?

The level of economic activity measured by real GDP per capita (1985 $US, international prices) has been above the $10.000 level since 1972.[2]

Following the pattern found by Grossman and Krueger (1995) we would expect indicators of environmental quality to remain constant or decline during the 70s and 80s. This would imply a decline in the environmental pressure. For some energy-related emissions, the changes in emissions in the period 1975-95 could indicate that this is actually the case.

Table 1. Growth rates of emissions of important air pollutants in Denmark 1975-95.

	1975-80	**1980-85**	**1985-90**	**1990-95**	**1975-95**
CO_2	3,5%	-0,6%	-3,3%	2,8%	0,6%
NO_x	4,4%	1,3%	-1,8%	-1,2%	0,6%
SO_2	1,4%	-5,4%	-11,9%	-4,0%	-5,1%
EC	2,6%	-0,6%	-2,1%	3,0%	0,7%
GDP	2,4%	2,0%	1,1%	2,0%	1,9%

Source: Appendix 1.

[2] From Penn World Tables that are used in most of the EKC studies.

The table displays growth rates of emission figures for carbon dioxide (CO_2)[3], sulphur dioxide (SO_2), nitrate oxides (NO_x), primary energy consumption (EC), and GDP in constant prices.

From the table, it is clear that environmental pressure in terms of emissions of CO_2 and NO_x did not decline during the period, whereas SO_2 emissions were drastically reduced.

None of the emissions have increased as much as GDP in the twenty-year period. Thus we may at least conclude that the emission intensity, i.e. the ratio of emissions to GDP, has been declining through this period. CO_2 emission intensity was rising in the second half of the 70s but declined in the 80s. In the first half of the 90s, it rose again. NO_x-intensity increased in the second half of the 70s, but declined in the rest of the period. SO_2 intensity declined throughout the twenty-year period.

The question is to which extent the overall decline in emission intensity was linked to the level of income. We can handle this question by decomposing emission rates in components reflecting the driving forces of emissions.

(1) $Z/GDP = Z/EC * EC/GDP$

where Z represents emissions. The growth rate of Z/GDP is then the sum of the growth rates in Z/EC and EC/GDP.

Table 2. Growth rates of emissions to energy consumption ratios and energy consumption to GDP ratio in Denmark 1980-95.

	1975-80	**1980-85**	**1985-90**	**1990-95**	**1975-95**
CO_2/EC	0,9%	0,0%	-1,2%	-0,2%	-0,1%
NO_x/EC	1,8%	1,9%	0,3%	-4,0%	0,0%
SO_2/EC	-1,1%	-4,8%	-10,0%	-6,7%	-5,7%
EC/GDP	0,2%	-2,6%	-3,2%	1,0%	-1,2%

Source: Appendix 1.

For the entire twenty year period, the changes in the ratios of CO_2 and NO_x emissions to energy consumption was very small compared to the changes in energy consumption per GDP. The combined effect of these two forces was not enough to outweigh the effect of economic growth. Thus, there is no EKC to explain in a strict sense. However, whatever has been achieved is primarily achieved via improvements in energy efficiency. The question of whether these achievements are linked to the income level is analysed in the following section. It should be noted that the figures in the last two sub periods are strongly affected by unusually low energy consumption in 1990 due to large electricity imports.

[3] The government also publishes adjusted CO2-emission figures. Adjusted CO2-figures are actual figures minus emissions due to unusually cold years (i.e., adjusted for heating degree days) and due to net exports of electricity.

SO_2/EC declined at a moderate rate in the 70s but at a relatively high rate during the 80s and 90s. In this case the reduction of this ratio has been far more important than the improvements of energy efficiency.

Thus, SO_2/EC is the only case where a possible linkage between a high-income level and less environmental pressure can explain an EKC type pattern.

The decline in SO_2/EC reflects to a large extent the conversion of fuel base of the power-producing sector from oil to coal. In the 70s, residual oil had a sulphur content 2.5 times as high as coal. From the mid 80s natural gas and renewable energy has also played an increasing role in Danish energy supply. During the 80s and the 90s regulation of sulphur content in fuels has been progressively more restrictive. The figures for emission factors and sector emissions for each sector are reported in Fenhann (1999)

Are these developments due to the high level of income in Denmark? Generally, the changes in the fuel base of the power sector and introduction of natural gas was a result of an energy policy emphasising supply security and balance of payments consideration. These objectives are hardly specific for rich countries and it is hard to see why the energy supply planning should be much different with a more modest level of income. It could, however, be argued that government subsidised expansion of renewable energy constitute an exception.

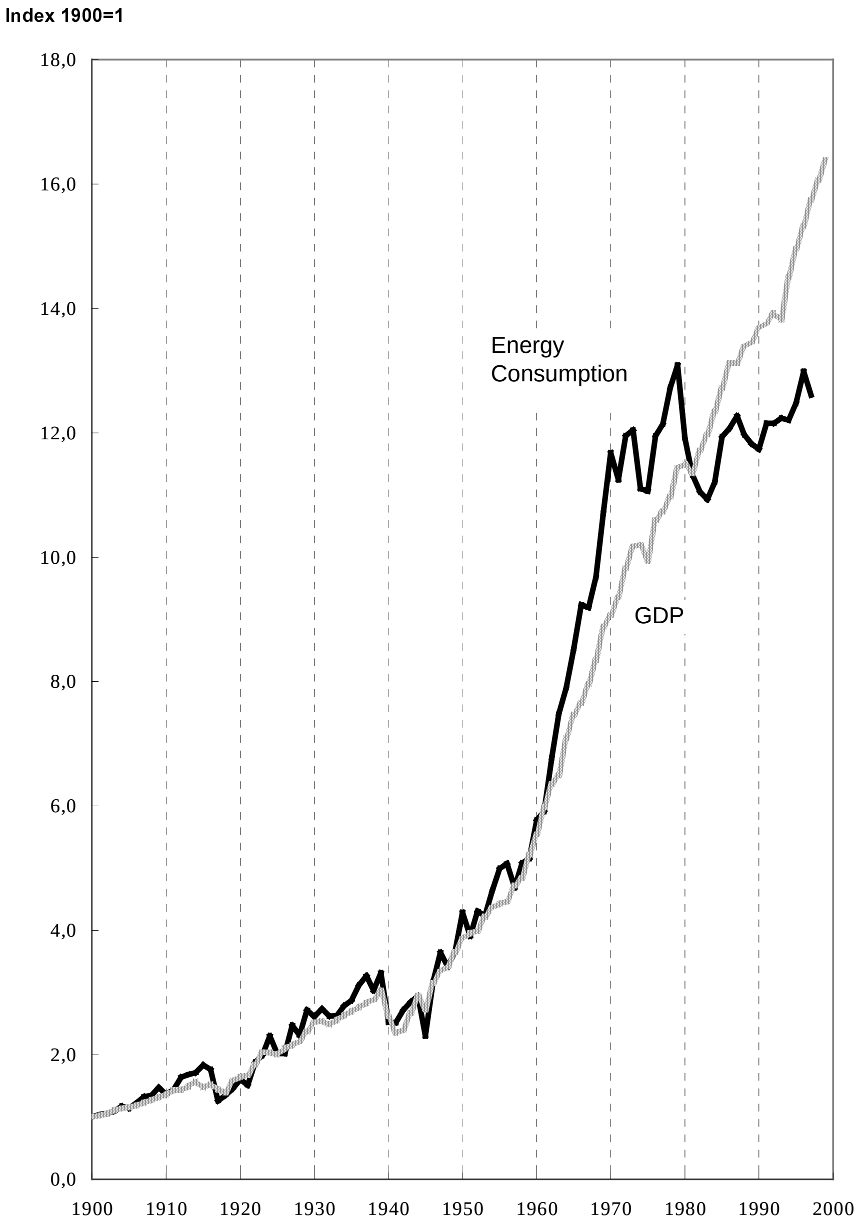
The environmental objective of energy policy became increasingly dominant during the 80s and the most important objective at the end of the 80s (Olsen 1993; Danish Ministry of Energy 1990). Thus, for the changes in emission rates in the 90s that are caused by regulation with an environmental objective, there is a case for a political economy explanation of a link between the higher level of income and the reductions in environmental pressure.

Generally, we can conclude that the data does not display EKC-patterns for CO_2 and NO_X. Latent patterns with EKC resemblance may, however, be found in the energy consumption. This is the theme of the following section. In the case of SO_2, the constant decline of emission rates throughout the twenty years period is partly caused by energy planning which at least until the late 80s had other objectives than emission reductions (although it was recognised as a side benefit). The high Danish income level can condition the emission reductions in the 80s if a connection between this level and a more stringent environmental regulation can be established. We return to that question in the section on political economy explanations below.

Growth and Energy Consumption in Denmark

At the end of the 20^{th} century, aggregate income as measured by GDP in real terms is about 16 times as large as at the beginning of the century. The gross energy consumption in Denmark has increased accordingly during the century. The diagram below shows the development of aggregate income and gross energy consumption in Denmark during this century.

Figure 1. Energy Consumption and Real GDP in Denmark in 20th Century



Source: Appendix 2.

The diagram shows that growth in gross energy consumption paralleled growth in aggregate income during the first half of the century. In the second half of the century, the pattern changed. First, from the 1950s through the early 1970s, gross energy consumption increased faster than the gross domestic product. This period was also the period in which we experienced historically unique high rates of economic growth. Then, from the early 1970s, the rapid growth of energy consumption ceased and during the next two decades it was fluctuating around a relatively stable level although gross domestic product continued to grow. This phenomenon can be termed *delinking* of energy consumption growth from economic growth.

This development gives rise to at least two questions. The first question relates to the relation between energy consumption and economic growth: how large a share of the growth in gross energy consumption that can be attributed to the economic growth, and how much growth in energy consumption results from qualitative changes of production and consumption patterns? The standard method for analysing this type of issue is to decompose the gross energy consumption into an aggregate output part and an energy intensity part.

The second question relates to the factors that determine the changes in the intensity of energy consumption and, particularly, whether this energy intensity changes *endogenously* as the level of GDP rises.

Decomposition of the Growth of Energy Consumption

The growth of gross energy consumption (E) can be analysed by decomposing it into the energy intensity (E/GDP) and aggregate income (GDP). It is usually assumed that the growth of aggregate income causes the growth of gross energy consumption. This assumption is not always accurate, as an analysis of the individual periods shows. In the table below, the changes in gross energy consumption are decomposed to the changes in energy intensity and growth.

Table 3. Decomposition of Annual Compound Growth Rates of Energy Consumption

	GDP	**EC/GDP**	**EC**
1900-14	3,3%	0,7%	4,0%
1914-22	2,2%	0,1%	2,3%
1922-39	3,0%	0,8%	3,8%
1939-48	1,9%	-0,5%	1,8%
1948-61	4,4%	0,3%	4,6%
1961-73	4,5%	1,6%	6,2%
1973-83	1,7%	-2,5%	-0,8%
1983-87	2,3%	0,6%	3,0%
1987-97	1,8%	-1,5%	0,3%
1900-97	3,0%	0,1%	3,1%

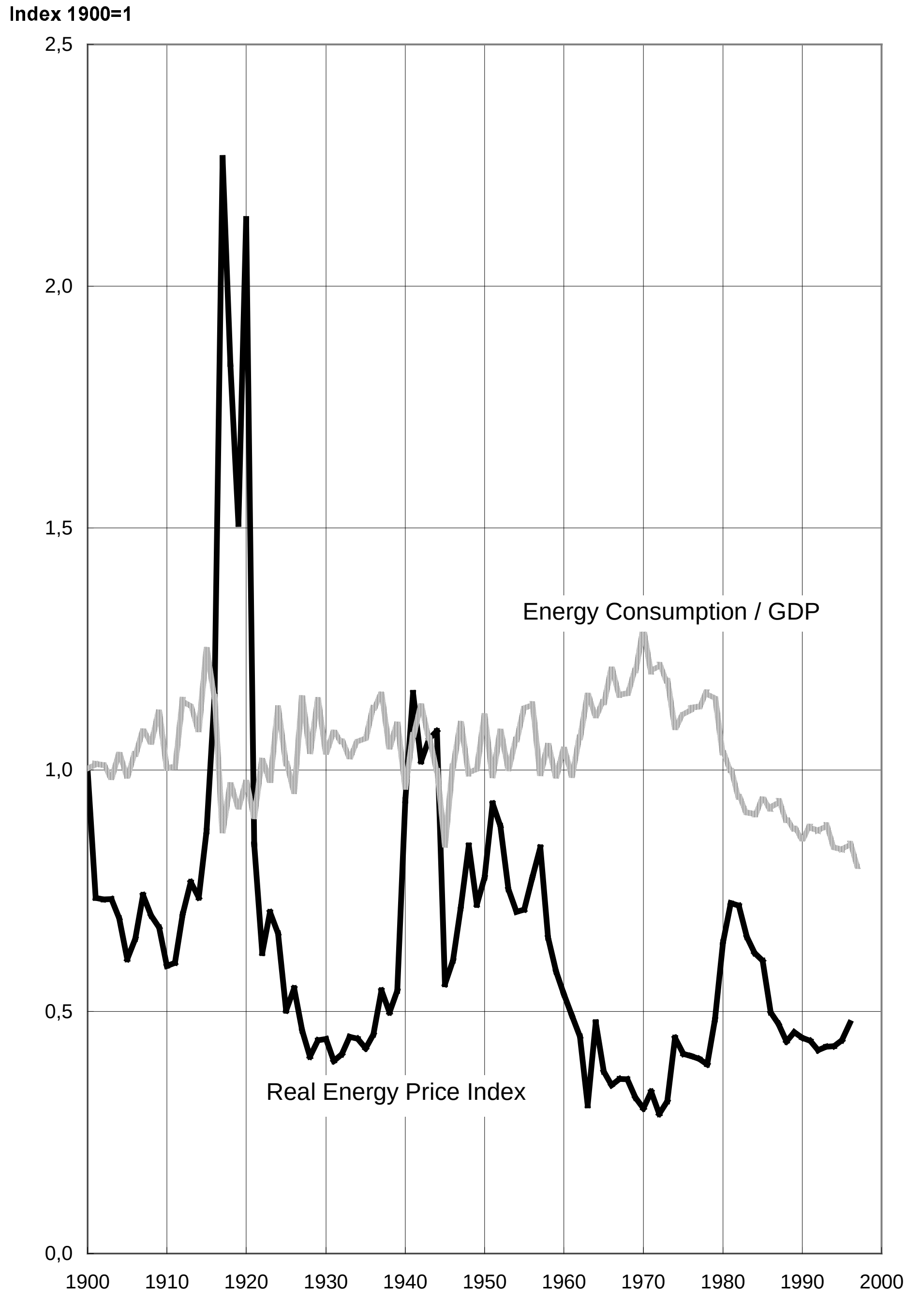
Sources: Appendix 2.

High growth rates of energy consumption in the 20th century occurred primarily in the periods with high rates of economic growth. It is noteworthy that the ratio of energy consumption to GDP grew faster in these periods too. This does not mean that there is a simple causality between economic growth and energy intensity (Experiments produced positive coefficients but only significant at 19% levels). But it shows that the causal chains between economic growth and energy consumption may be more complicated than often assumed.

The period from the early 1970s where energy consumption growth was de-linked from economic growth was also interrupted by a short period in 1983-87 of relatively high economic growth with growth in energy intensity as well. In other words, even if economic growth in a high-income economy is assumed to be associated with an offsetting growth in energy efficiency, the Danish experience shows that this is not the case under all circumstances.

The prime suspect for changes in energy efficiency must, off cause, be changes in relative prices. The relevant price concept in this context is the real energy price. In the diagram below, the intensity of energy consumption is compared to a real energy price index, that is, energy price relative to the GDP-deflator. The energy price is defined as energy good expenses per energy consumption in the period 1966-96 and the import price index for fuel before that. Thus the energy taxes introduced in the 80s are reflected in the price index.

Figure 2. Energy Intensity and Real Energy Price in Denmark 1900-1996



Source: Appendix 2.

The diagram shows that the changes in intensity of energy consumption follow the changes in the real price index quite closely. In particular, it should be noted that the long periods of high growth before WWI, in the 20s, in the post war period, and in the 60s were supported by declining real energy prices. This is also true for the short growth period of 1983-87. Similarly, the delinking in the 70s expressed by the steep drop of energy intensity follows a correspondingly steep increase of the real energy price.

Energy Consumption and Income. Empirical Analysis.

Even if economic growth and the real energy price seem to be the main factors behind the pattern of energy consumption growth, EKC mechanisms could be functioning behind the data, although not visible in the figures and table above. To test for this a series of statistical analyses are performed.

Bentzen (1993) found a short-term price elasticity of 0,139 for energy consumption and tested for changes in the parameters before and after 1973, but did not find significant changes. Bentzen and Engsted (1992) studied the household energy demand in Denmark using co-integration techniques and error correction models. They estimated the elasticities of income, own price and heating degree-days to gross energy consumption. The long-term income elasticity was found to be 1.213 and the long run price elasticity was found to be –0.465. The short run income elasticity was 0.666 and the short run price elasticity was -0.135. In a later study, Bentzen (1993) estimated the same model on data covering 1900-91 but did not find the same stable relations for this longer period.

The price elasticity for aggregate industrial energy consumption was found by Statistics Denmark (1999) to be -0.16 for the first year accumulating to -0.25 over the following years. For household energy consumption, long-term price elasticities were -0.62 for heating, -0.30 for electricity and –0.69 for transport (but about –0.5 before 1978). All parameters are estimated on time series for 1966-95.

These studies did, however, not test for dependency of energy consumption on the level of GDP. In the following, I shall attempt to do this. The estimation models used in the following are identical to the set of estimation models used by Bruyn and Opschoor (1994) except that I have added a variable reflecting temperature variations, heating degree days. All models are transformed to first differences of logarithms.

The *base* assumption is that energy consumption depends only on real GDP, the real energy price, P, and heating degree-days, H.

(4) $\text{dln } E_t = \alpha(\text{dln } Y_t) + \beta(\text{dln } P_t) + \chi(\text{dln } H_t)$

Testing for EKC-type patterns can be done with a quadratic function or simply by including the *level* of GDP as an explanatory variable. The *quadratic* model can be based on

(5) $E_t/Y_t = \gamma Y_t^{(\gamma + \phi \ln Y)}$,

that can be rearranged to

(6) $E_t = \gamma Y_t^{(\gamma + 1 + \phi \ln Y)} = \gamma Y_t^{(\alpha + \phi \ln Y)}$

The model can be specified by taking logarithms and first differences and adding real energy price and heating degree-days.

(7) $d\ln E = \alpha(d\ln Y_t) + \phi\{(\ln Y_t)^2 - (\ln Y_{t-1})^2\} + \beta(d\ln P_t) + \chi(d\ln H_t)$

The alternative test for income *level* dependency is simply

(8) $d\ln E_t = \alpha(d\ln Y_t) + \phi Y_t + \beta(d\ln P_t) + \chi(d\ln H_t)$,

where the income level is strongly correlated with time and therefore may be interpreted as a representative of time. To test whether this can be the case, we substitute income level by *time* and look for differences.

(9) $d\ln E_t = \alpha(d\ln Y_t) + \phi T_t + \beta(d\ln P_t) + \chi(d\ln H_t)$

The regressions were performed on data sets covering two different time periods. The first data set covered the period 1902 - 1992 and the second the period 1948 - 1992. The parameters estimated on the long data sets are were generally insignificant except for GDP growth and heating degree-days. Obvious explanations for this can be the two world wars in the first half of the century, during which normal relations between economic activity and energy use was suspended. Fuel rationing also occurred during times of peace.

The parameters estimated on the shorter data set are presented in the table below.

Table 4. Regression results for 1948 to 1996 (N=48, *P-values below estimates*)

	Constant	α growth	ϕ	β energy price	χ heating degree days	R^2
(4)	-0,007	0,996		-0,129	0,372	0,70
base	*39%*	*0%*		*0%*	*0%*	
(7)	-0,006	3,193	-0,186	-0,126	0,383	0,71
quadratic	*49%*	*9%*	*24%*	*0%*	*0%*	
(8)	0,017	0,866	0,000	-0,125	0,376	0,71
GDP level	*34%*	*0%*	*13%*	*0%*	*0%*	
(9)	1,172	0,854	-0,001	-0,126	0,377	0,71
time	*11%*	*0%*	*11%*	*0%*	*0%*	

Source: Appendix 2 and Author's calculations.

The table shows results of four models that differ with respect to one explanatory variable. Model (4) has growth, real energy price, and temperature as explanatory variables. Model (7) additionally includes the quadratic model. Model (8) includes instead the level of aggregate output as an explanatory variable. The additional regressor in model (9) is time.

In all four models, the price elasticity is highly significant. The size of app. 0.13 corresponds to the results of other estimates of short term price elasticities referred to above. The coefficient for temperature is also robust, which hardly is surprising. The constant is insignificant in all cases.

In the base model, income elasticity is practically 1 and significant. None of the results from estimation of EKC-patterns offer significant evidence of existence of such patterns. Actually, the sign of the parameter for the GDP level is positive, but still not acceptable significant. About the same share of the variation is explained by the same variables as in the base model, so the EKC hypothesis does not seem to offer any improvement to the understanding of how energy consumption is determined.

Earlier analyses of a similar data set led to similar conclusions although weaker. The data set used here reflects the improvements made by the Statistical Office in a major revision of the national accounts as well as a major revision of the energy statistics.

Thus, the evidence found here does not lend support to the hypothesis that the de-linking of energy consumption and the related pollution effects is a function of aggregate income.

A Structural Explanation

Despite the lack of evidence of EKC patterns in the Danish data analysed above, shifts to industrial structures typical for high income countries could have caused a decline in energy consumption in the latest decades of the century. Such industries are often assumed to be service industries and knowledge intensive industries. Since it is reasonable to expect these industries (except for the transport industry) to be less energy intensive than standard manufacturing industries, such a change could support the downward trend of overall energy intensity.

A number of studies have been published on similar issues. Munksgaard et al. (1998) studied the CO_2 emissions due to private consumption. The study found that the structural changes in consumption composition (and thus in industrial structure) was insignificant as compared to the effects of on the one hand increasing consumption growth and on the other hand energy efficiency growth in the individual industries.

In model simulations on effects on carbon dioxide emissions of changes in demand structure from private consumption to government consumption, Jespersen et al. (1999) similarly found that the effects had the expected sign, but were very modest.

Shipper et al. (1995) found considerable decreases of manufacturing energy consumption from 1973 to 1991 in Western Germany, USA, and Japan due to changes in the structure of industrial output. For Denmark, however, the changes were negligible. As some of the most important structural shifts behind the structural EKC explanations involve changes to less weight of manufacturing in total output, a similar analysis on the entire production sector is presented below.

As discussed in chapter 2 above changes in industrial structure may explain the downward trend in the energy to GDP ratio. This can be analysed by further decomposing energy consumption:

(11) $Z = GDP * Z/EC * \mathbf{ye}$

where GDP is Gross Domestic Product in constant factor prices, Z/GDP is the intensity of emissions, Z/EC is the emission per unit of EC, EC/GDP is the intensity of energy consumption, **y** is a row vector of industrial structure in which the elements are the industries' share in GDP, and **e** is a column vector of the intensity of energy consumption of each industry. The matrix product **ye** is a scalar equal to EC/GDP. The following figure shows the changes in these vectors.

In this section, the national accounts and energy statistics from before the above mentioned revisions are used because they provide data on industrial level back to 1966.

Table 5. Industrial Structure and Industry Specific Intensity of Energy Consumption (EC_i/GDP_i for industry i) in Denmark 1966 and 1991.

Changes in structure and intensity 1966-91

	Intensity of energy Consumption (EC) TJ/80-DKR Mio		Structure of GDP (in 80 factor prices) Percent	
	1966	1991	1966	1991
Agriculture	3,3	2,0	7%	6%
Mining	7,1	0,3	0%	4%
Manufacturing	3,6	2,4	19%	17%
Public utilities	0,5	0,3	1%	2%
Construction	0,5	0,8	12%	5%
Transportation	2,0	2,9	9%	8%
Private services	0,8	0,7	34%	37%
Public services	0,7	0,6	17%	21%
Industries total	1,6	1,2	100%	100%

Sources: Statistics Denmark (various) and author's calculations.

According to table 6, the most energy intensive sectors in 1966 were mining, agriculture, manufacturing, and transportation. Less energy intensive sectors were public utilities, construction, private services, and public services.

From 1966 to 1991 the shares of agriculture, manufacturing, and transportation in total GDP actually declined. The share of the mining sector did, however, rise approximately as much as the share of the other three energy intensive industries together declined. This was a result of oil and gas extraction in the North Sea.

The low energy intensive industries like public utilities and private and public services increased their share, but in total only by the same order of magnitude as the construction sector's share fell. Thus, there were some changes in the expected direction, but the balance between energy intensive and energy light industries did not change significantly.

The industry specific intensities of energy consumption did, however, fall in all industries except transportation and construction. The large drop in the mining sector reflects the fact that this sector in 1966 was a negligible stone and chalk supplier while it in 1991 had become a large high value added oil and gas supplier.

The total effects of the aggregate energy consumption/GDP ratio can be decomposed into a structure and an intensity effect as shown in the table below.

Table 6. Calculation of Structure and Intensity Effects

Energy Consumption (EC) with constant factors					
GDPi/GDP	66-struct.	91-struct.	66-struct.	91-struct.	91-struct.
ECi/GDPi	66-intens.	91-intens.	91-intens.	66-intens.	91-intens.
GDP	66-level	91-level	91-level	91-level	66-level
	EC (TJ)	EC (TJ)	EC (TJ)	EC (TJ)	EC (TJ)
Agriculture	49732	50089	57622	81859	26419
Mining	1293	5101	115	108427	2690
Manufacturing	145831	167418	180720	255812	88302
Public utilities	1211	2840	1432	4546	1498
Construction	13258	15527	37848	10299	8189
Transportation	39053	89116	106920	61635	47003
Private services	62865	104900	97952	127481	55328
Public services	25542	50561	41333	59163	26668
Industries total	338785	485552	523941	709222	256097
Percent changes 1966-91					
		Actual	If fixed 1966		
			Structure	Intensity	Level
Agriculture		1%	16%	65%	-47%
Mining		295%	-91%	8286%	108%
Manufacturing		15%	24%	75%	-39%
Public utilities		135%	18%	275%	24%
Construction		17%	185%	-22%	-38%
Transportation		128%	174%	58%	20%
Private services		67%	56%	103%	-12%
Public services		98%	62%	132%	4%

Sources: Statistics Denmark (various) and author's calculations.

The upper part of the table should be read as follows. The first two columns show the actual energy consumption in each of the sectors in 1966 and 1991, respectively. The third, fourth and fifth column show what the energy consumption in each sector would have been in 1991 if the industrial structure, the energy intensity in each industry or the level of GDP was the same as in 1966, respectively.

In the lower part of the table, the first column shows the actual increase in energy consumption in each sector from 1966 to 1991 in percent of the 1966 energy consumption. The next three columns show the increase if the corresponding column above had shown the actual energy consumption in 1991. In other words if the industrial structure, energy intensity or GDP level had been the same as it was in 1966.

The total shows that energy consumption would have increased almost as much as it actually did if the industrial structure had been unchanged from 1966. If the industrial energy efficiency had not increased, however, aggregate energy consumption would have grown twice as much. Finally, without economic growth since 1966, the improved energy efficiency and structural change together would have led to a quarter less energy consumption in 1991 than in 1966.

The conclusion is that changes in industrial structure have had an impact on energy consumption in the expected direction. The magnitude of this impact is, however very modest, particularly when compared with the forces set in motion by increased energy efficiency and economic growth.

Increased energy efficiency in the individual industries is the fundamental cause of the decline of aggregate intensity of industrial energy consumption and thus in turn of most of the de-linking of fossil fuel related emissions from economic growth.

This leads to the conclusion that the progress in industrial energy-efficiency over the two and a half decade was primarily a result of more energy efficient production patterns within each industry rather than of changes in industrial structure.

A Political Economy Explanation

Shifts in Collective Preferences for Environmental Goods

Technical development in the energy supply sector has also contributed much to the energy savings in industries and households. For instance, the share of conversion loss in fuel consumption in the power and heat producing sector that was from 48% in 1972 to 35% in 1998 (The Danish Energy Agency 1999). These achievements correspond to more than 50PJ in 1998 or 6% of gross energy consumption in Denmark in 1998.

During the 90s, one of the most important developments has been to shift from centralised large power plants to smaller and combined heat and power plans. The energy savings resulting from this and other energy sector policies has according to The Danish Ministry of Finance (1998) been the largest single factor in reducing aggregate energy consumption in the period 1988-96.

If these developments should be related to the income level as suggested by the political economy explanations of EKCs, it should be through shifts in environmental preferences that on the one hand is related to income level and on the other hand is materialised in government energy planning.

The evidence presented above suggests that de-linking of fossil fuel related emissions from economic growth are rooted in energy savings rather than in emission control measures. Of course, environmental regulation could theoretically have prevented a latently increasing trend in the pollutant content of fuels but there is to my knowledge no sign of this. Thus, increased energy efficiency is the factor that primarily is responsible for de-linking of fossil fuel related emissions.

The empirical evidence did, however, not support any explanation of increasing energy efficiency as endogenously linked to economic growth. On the contrary, the relative prices seem to be able to explain it quite well.

On the other hand, consumer prices are to a very high degree determined by the government – at least since 1986. Thus, it could be argued that the de-linking was an effect of increasing per capita income leading to more environmental friendly median voter preferences which in turn resulted in political action in terms of energy taxes.

Andersen (1988a, 1988b) studied the factors behind the increasing environmental awareness in Denmark. He addressed three different angles explaining the rise of environmental concern from the late 60s through the end of the 80s. First, the class angle focuses on the emergence of a new white-collar middle class, particularly in the reproductive public sector (education, health and social service). Environmental policy is one of the issues on which the mobilisation of the middle class as a social force is based. Second, the value angle stresses the role of the increasing prosperity since the Second World War. As the basic needs of economic security ('economic growth') and physical security ('law enforcement' and 'defence') become satisfied the more intellectual needs gain in importance. The traditional distribution conflict is gradually replaced by conflict between materialism and post-materialism. This view is consistent with the fundamental assumption in neo-classical theory of declining marginal utility of consumption. The structural angle sees environmental concern as just an element in a broader misbelief in industrialism and the ideals and organisational forms associated with it.

The first two angles are criticised by Andersen (1988a) for not relating to the content of environmental problems and policies. Environmental problems are not 'luxury problems' but are related to the survival of humanity. All of the angles are in some way or another related to paradigm shifts to post-materialism, post-industrialism, postmodernism, soft, green, and female values. They do however neglect the dissemination of knowledge about the environment and the effects of human activities on the environment. New knowledge is, according to Andersen the missing link in these theories, which explain the increasing environmental awareness found in recent decades.

In the subsequent empirical analysis Andersen (1988b) found that the empirical facts did not support the idea of a changing class structure behind the increase in environmental awareness except for the fact that farmers tend to be less 'environment positive' than other citizens. Apart from this, the only social factors that could explain variations in the 'environmentally positive' index were age and level of education. Age and education are critical factors in explaining information dissemination. Education for obvious reasons and age because fundamental political attitudes are formed in one's younger years.

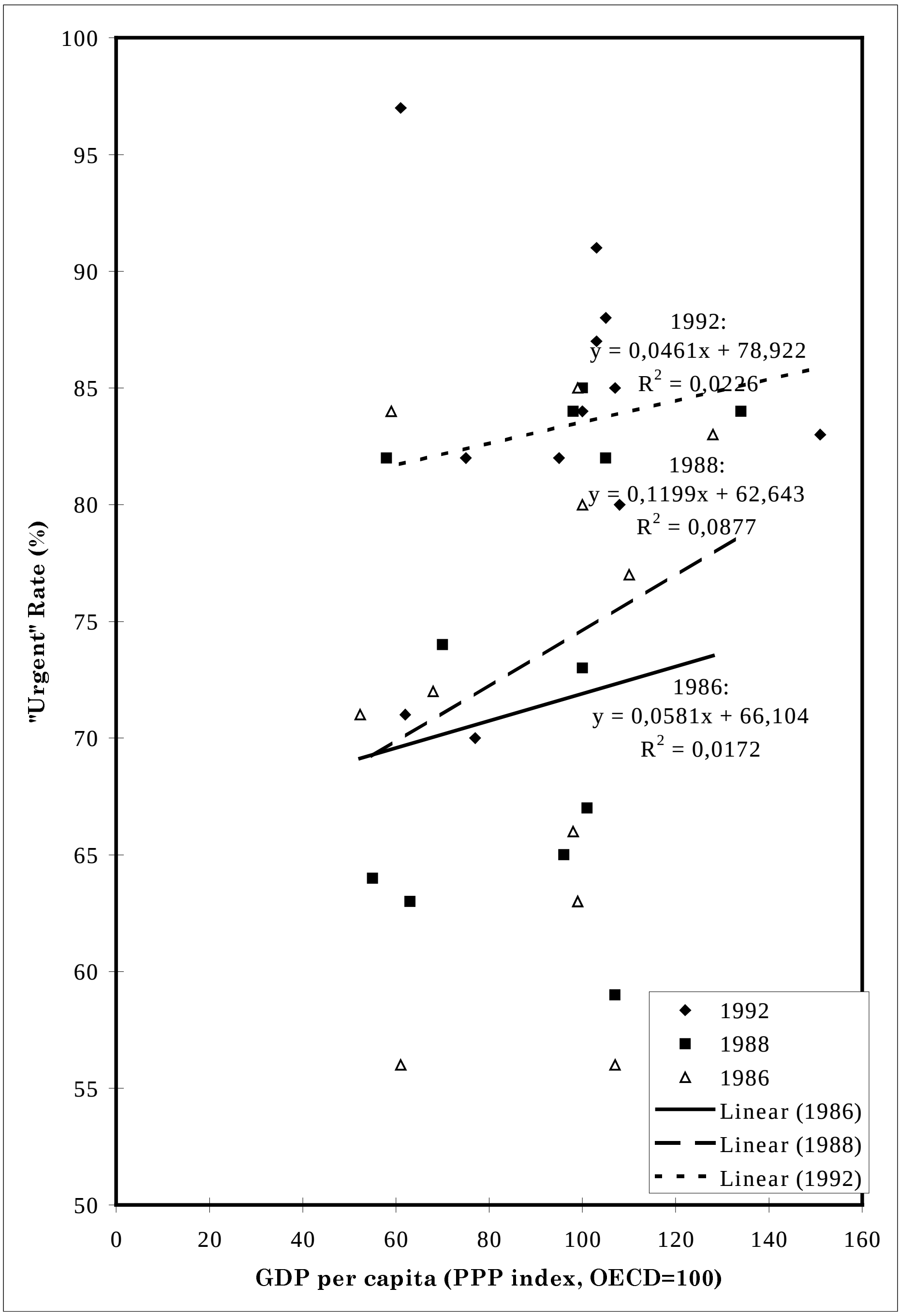
Income level and environmental preferences. Empirical Evidence.

It is also possible that the rise in environmental awareness was nurtured by the high growth rates of employment and income in the years from 1982 to 1986. The recession in the following years did, however, not prevents the environmental policy preference from increasing further. According to The Commission of the European Communities (1986, 1988, 1992) the share of voters that considered environmental protection an immediate and urgent problem rose from 77% in 1986 to 82% in 1988 and 87% in 1992.

The causal link between income level and the priority given to the environment by the voters is probably not meant in such a narrow way but nevertheless these data shows that the concern for the environment was relatively independent of income changes over a period of a decade or so.

The statistical relationship between income level and environmental awareness can also be studied on a cross European basis. The figure below uses data from three surveys (1986, 1988, and 1992) about the percentage of the population in twelve EU countries considering environmental protection and pollution fighting "an immediate and urgent problem". These data are related to the relative income level in each country measured by a Purchase Power Parity (PPP) index with OECD average = 100. The span between the country with the lowest income level and the country with the highest income level approximately corresponds to the span between the income level of a medium income economy and a high-income economy on the global level. Thus, these comparisons can shed some light on the issue of the income - environmental preference relation. If the hypothesis of an increasing pressure for a tighter environmental policy over this interval is true on the global scale, then it should be possible to establish a statistical relationship between the data in figure 3.

Figure 3. Share of population considering "environmental protection an immediate and urgent problem" compared with relative income levels in 1982, 1986, and 1992 in 12 European countries.



Source: Commission of the European Communities (various).

In the figure a trendline for each of the years is shown along with the regression models, the estimated coefficients and the R-squared. All of the regression lines have the right slope but none of them have R-squareds of any useful level. The estimated coefficients turned out to be highly insignificant and the F-value much below the required critical value. Experiments with non-linear regressions (log-log and polynomial) did not produce more significant estimates (in the case of polynomial, however, a higher R-squared).

If this relationship had been significant and if it was justifiable to use such a cross-section relationship in predicting future time series levels, then the results in figure 9 could be used for predicting the future of the public opinion about environmental policy in medium-income economies. As the diagram shows very clearly, an increase in the level of income about 300% (from index = 50 to index = 150) would result in an increase of about 3-10 percentage units. With a 2% growth rate such an increase would take 55 years to reach. The position of the curves in relation to each other, however, indicates an increase of 10-15 percentage units over the six years from 1986 to 1992. Comparing these figures leads to the conclusion that though there might be something to the hypothesis of the public opinion being dependent of the national income level, it can far from offer a deterministic explanation of the increasing environmental concern in Western Europe.

Conclusions and Final Remarks

In the first part of the paper I have reviewed the empirical evidence and the theoretical justification behind the EKC hypothesis. I concluded that the evidence did not support the EKC as a general economic law.

Evidence of EKC patterns have been found for urban pollution problems, but the EKC-inference that they should justify an endogenous delinking of environmental pressure from economic growth have been questioned.

For the international and "invisible" environmental problems there is no evidence of EKC-patterns that can be interpreted in terms of endogenous delinking.

One of the implications for long term environmental strategies in DCs is that environmental pressure following an EKC-pattern is a feasible option in development planning, albeit not necessarily a recommendable one. *Channelling through* might be a more favourable strategy from a social welfare point of view.

For industrial countries as well, the implication for environmental strategies is that at least history tells us, that reducing pollution and expanding output simultaneously has been possible for some urban pollution problems. This makes a case for strategies aiming at similar results for the international and invisible pollution problems.

The Danish experience shows that the strength of the forces making economic growth working in favour of the environment are rather small compared to the forces that make economic growth working against the environment.

In the second part of the chapter I attempted to establish links between some of the most important pollution problems in Denmark and the level of economic activity or income. The results were that two of the suggested mechanisms, changes in industrial structure and elastic environmental preferences could be contributing to the delinking of emissions from economic growth. *The magnitude of these forces was, however, found to be too small to justify any reliance of long term development planning on them.*

This could be the case if such standards were unaffordable for developing countries. However, this does not seem to be the case. A number of developing countries have already followed the UN call for phase out of leaded gasoline and are introducing less costly converters and engine efficiency in their standards and incentive regulations (see, e.g., Lovei 1997).

Delinking of fossil fuel related emissions from economic growth has in Denmark been associated with fuel substitution driven by energy prices, government planning of the power and heat generation sector, and emission regulation by standards and taxes. The general conclusion is that none of these policies seem to be conditioned by a high level of income. Thus, they should be applicable in poorer countries as well. This provides some optimism as to the feasibility of "tunnelling through" an EKC of energy consumption and related emissions in countries at lower income levels.

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Appendix 1

Emissions, Gross Energy Consumption and GDP in 1995 Factor Prices in Denmark 1975-95 (selected years).

		1975	**1980**	**1988**	**1990**	**1995**
CO_2	*(kt)*	52575	62565	60796	51319	58807
NO_x	*(t)*	217702	269717	287040	262310	247447
SO_2	*(t)*	421444	452490	342462	182214	148871
EC	*(TJ)*	733045	832333	807265	725565	839390
GDP	*(BioDKK95)*	697	784	866	916	1010

Source: Fenhann (1999), appendix 2.

Appendix 2. Data on growth and energy consumption in the 20th century.

	Gross energy consumption	GDP (mio DKK, 95-factor prices)	Real Energy Price Index	Heating Degree Days	Grs.Ener. Cons./ GDP		Gross energy consumption	GDP (mio DKK, 95-factor prices)	Real Energy Price Index	Heating Degree Days	Grs.Ener Cons./ GDP
1900	66,8	58,3	164,7	3382	1,15	**1950**	286,3	225,1	128,0	3104	1,27
1901	69,3	59,8	121,1	3375	1,16	**1951**	260,9	230,5	153,3	3040	1,13
1902	70,7	61,2	120,5	3551	1,16	**1952**	287,8	232,9	145,6	3337	1,24
1903	73,1	64,8	120,6	3182	1,13	**1953**	282,6	246,1	124,0	2878	1,15
1904	78,2	66,2	114,1	3267	1,18	**1954**	309,4	254,3	116,4	3234	1,22
1905	76,1	67,3	100,2	3362	1,13	**1955**	333,2	258,5	117,1	3432	1,29
1906	81,9	69,2	107,2	3128	1,18	**1956**	338,9	260,5	127,9	3470	1,30
1907	88,7	71,8	122,0	3261	1,24	**1957**	312,9	275,2	138,2	3095	1,14
1908	89,8	74,1	115,0	3342	1,21	**1958**	339,3	282,3	107,6	3584	1,20
1909	98,5	76,9	110,9	3502	1,28	**1959**	344,2	304,3	95,9	2980	1,13
1910	91,1	79,3	97,9	3069	1,15	**1960**	385,4	323,1	88,4	3229	1,19
1911	96,3	83,5	98,9	2987	1,15	**1961**	394,8	348,7	81,1	2929	1,13
1912	109,5	83,5	115,4	3383	1,31	**1962**	452,4	370,4	73,8	3340	1,22
1913	112,1	86,6	126,5	2976	1,29	**1963**	499,5	378,3	50,4	3604	1,32
1914	114,3	92,1	121,2	2997	1,24	**1964**	527,1	413,6	78,7	3251	1,27
1915	122,5	85,7	143,7	3479	1,43	**1965**	568,2	435,4	61,9	3371	1,31
1916	117,8	89,3	190,0	3185	1,32	**1966**	616,6	446,0	57,3	3391	1,38
1917	84,2	84,0	373,0	3532	1,00	**1967**	613,6	464,1	59,4	2962	1,32
1918	90,1	81,3	302,8	3138	1,11	**1968**	646,2	486,7	59,2	3229	1,33
1919	97,0	91,8	248,4	3470	1,06	**1969**	715,0	518,0	53,1	3457	1,38
1920	107,1	96,1	352,2	3097	1,11	**1970**	779,8	528,9	49,5	3528	1,47
1921	101,0	97,5	139,4	2932	1,04	**1971**	750,7	545,1	55,1	3058	1,38
1922	125,3	107,4	102,4	3516	1,17	**1972**	797,7	572,6	47,5	3243	1,39
1923	133,0	118,7	116,3	3396	1,12	**1973**	804,1	592,8	51,8	3160	1,36
1924	153,7	119,1	109,0	3436	1,29	**1974**	741,3	594,7	73,5	2901	1,25
1925	134,9	116,3	82,6	3210	1,16	**1975**	738,4	579,6	68,0	2940	1,27
1926	134,8	123,2	90,3	3178	1,09	**1976**	797,3	617,7	67,2	3468	1,29
1927	165,1	125,6	75,9	3346	1,31	**1977**	810,6	625,4	66,3	3135	1,30
1928	154,4	129,8	67,1	3223	1,19	**1978**	849,3	639,5	64,3	3233	1,33
1929	181,5	138,5	72,6	3476	1,31	**1979**	873,9	666,2	79,7	3536	1,31
1930	174,3	146,8	73,0	3038	1,19	**1980**	795,0	670,5	105,8	3407	1,19
1931	183,0	148,4	65,6	3377	1,23	**1981**	756,3	661,5	119,3	3354	1,14
1932	175,2	144,5	67,9	3142	1,21	**1982**	738,0	682,9	118,4	3177	1,08
1933	175,5	149,2	73,8	3205	1,18	**1983**	729,7	697,9	107,8	3032	1,05
1934	185,9	153,6	73,1	2738	1,21	**1984**	748,0	719,4	102,3	3117	1,04
1935	191,9	157,1	69,8	3125	1,22	**1985**	796,6	741,5	99,6	3599	1,07
1936	208,0	161,0	74,6	3215	1,29	**1986**	805,7	764,8	82,0	3479	1,05
1937	218,1	164,9	89,6	3218	1,32	**1987**	819,3	764,9	78,2	3478	1,07
1938	202,6	168,9	82,0	2855	1,20	**1988**	799,3	779,5	72,2	2933	1,03
1939	221,5	176,9	89,5	3145	1,25	**1989**	789,4	785,2	75,3	2721	1,01
1940	168,6	152,6	154,2	3800	1,10	**1990**	783,2	796,9	73,5	2679	0,98
1941	168,2	137,0	190,9	3738	1,23	**1991**	811,2	803,1	72,4	3074	1,01
1942	181,5	140,2	167,6	3697	1,30	**1992**	811,0	811,7	69,2	2938	1,00
1943	190,0	155,7	175,2	2917	1,22	**1993**	816,8	805,4	70,3	3446	1,01
1944	196,6	171,9	177,9	3130	1,14	**1994**	814,5	845,6	70,5	3179	0,96
1945	153,8	159,0	91,7	2943	0,97	**1995**	832,9	872,1	72,5	3334	0,96
1946	212,0	183,8	99,8	3185	1,15	**1996**	866,6	893,4	78,6	3807	0,97
1947	243,3	194,1	117,7	3464	1,25	**1997**	841,3	917,4	#N/A	3269	0,92
1948	227,8	200,5	138,8	2968	1,14	**1998**	#N/A	936,6	#N/A	3255	#N/A
1949	244,6	212,8	118,7	2724	1,15	**1999**	#N/A	955,1	#N/A	3056	#N/A

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